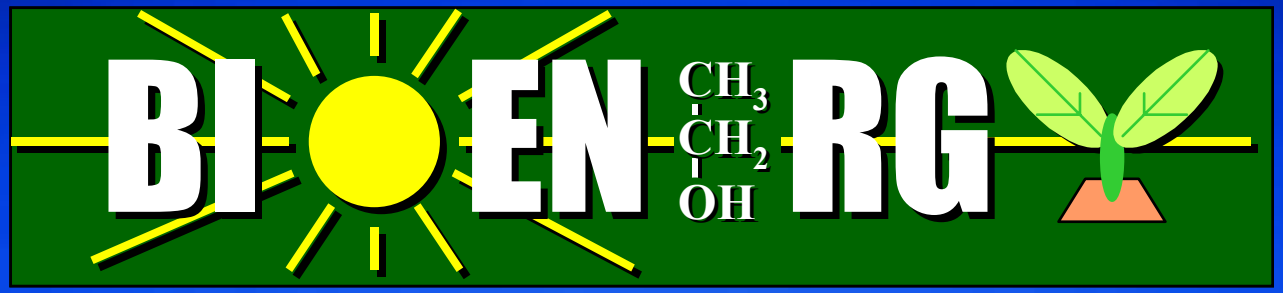


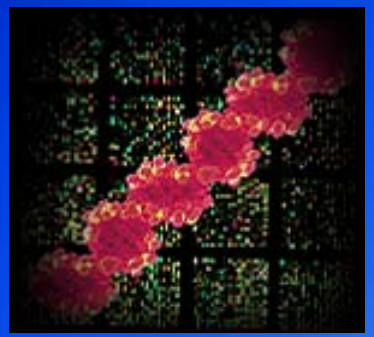
Cellulase Cost Reduction

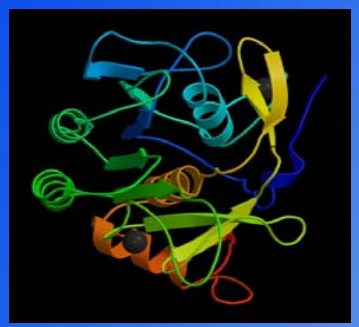
Enzyme Sugar Platform Project Review
Golden, Colorado
May 2, 2003

Joel R. Cherry
Novozymes Biotech, Inc.

novozymes

Novozymes in brief





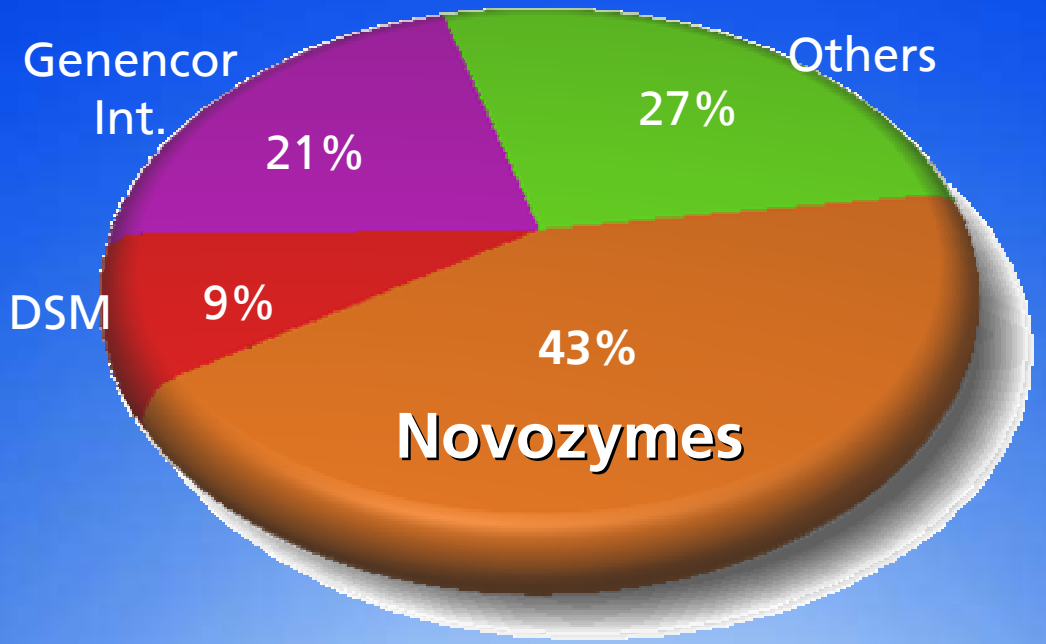
- **Industrial enzymes**
  - Established world business in the 60's
  - Continued World Leader (43% world-wide market share)
  - Today, one of the world's largest biotech companies
- **Revenue 2001**: ~ $700 million
- **> 600 products** based on recombinant proteins
- **Market products in > 120 countries**
- **Employees: ~ 3,500**
- **Leading-edge biotechnology expertise**
  - 12-13% of revenue spent on R&D
  - 650 R&D scientists
  - More than 4,000 patents
  - 35 new products in the last five years

novozymes

Novozymes

Biotech-based World Leader in Enzymes & Microorganisms

Total enzyme market value 2001: $1.63 Billion



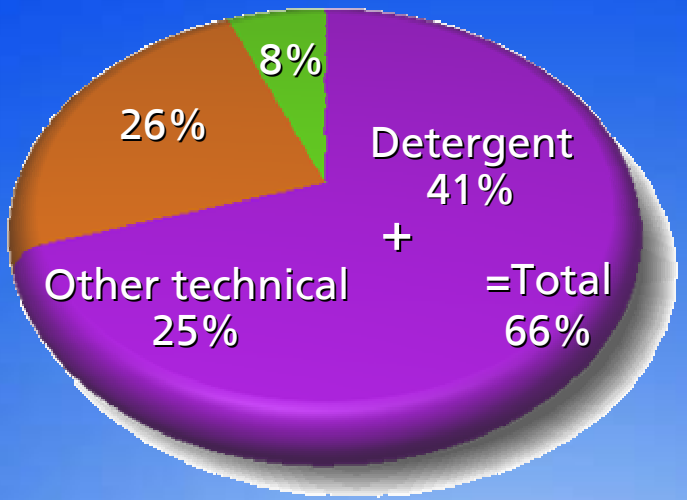
Source: Novozymes' estimate 2002

novozymes

Net turnover per business area 2001

Total NZ Turnover 2001: $700 Million

Animal feed enzymes



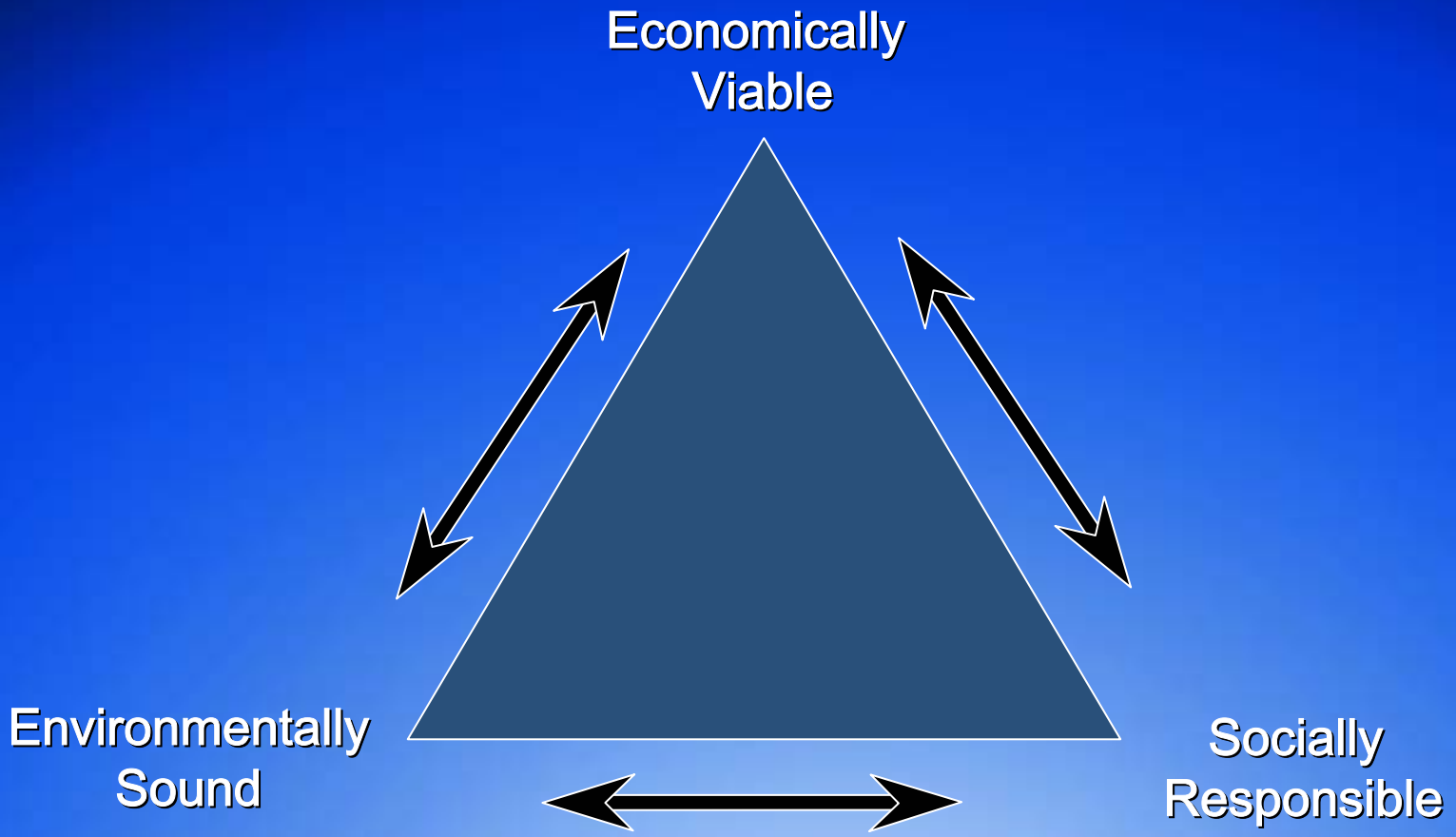
Beverage & Cereal

Technical enzymes

novozymes

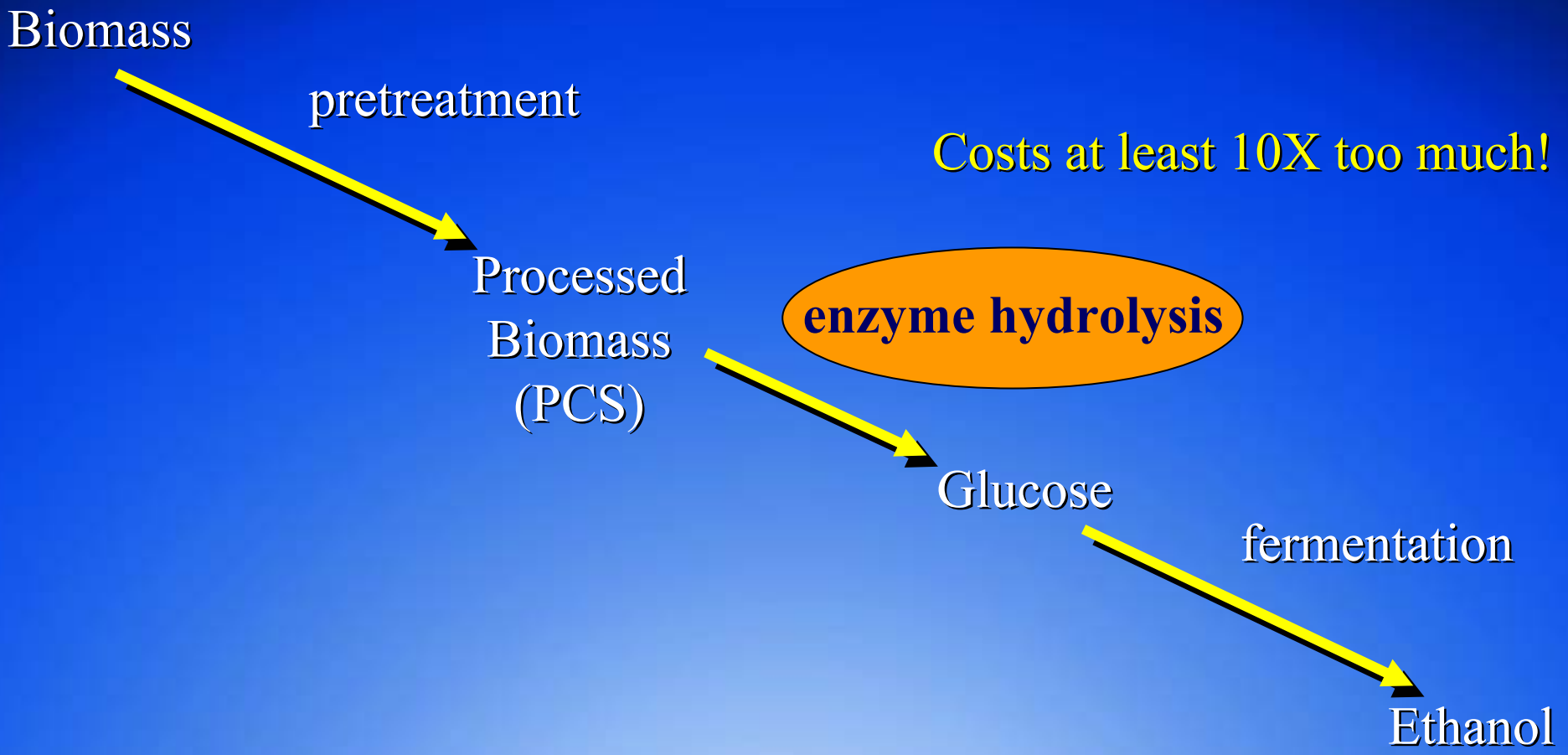
The Triple Bottom Line

Named # 1 on the Dow Jones Sustainability Index, September 2002



novozymes

Converting Biomass to ethanol



Corn grain versus corn stover: What's the difference?

Corn

72% Starch
10% Cellulose/Hemicellulose
9% Protein
4.5% Oil
3.5% Other

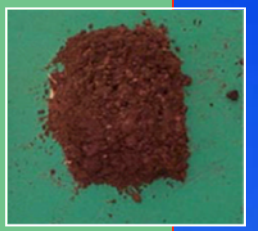
Yield = 114 gallons ethanol/dry ton
= 18 lbs. corn grain/gallon
Enzyme usage ~ 1 g protein/gallon

Corn stover

38% Cellulose
32% Hemicellulose
17% Lignin
13% Other

Acid pretreated corn stover

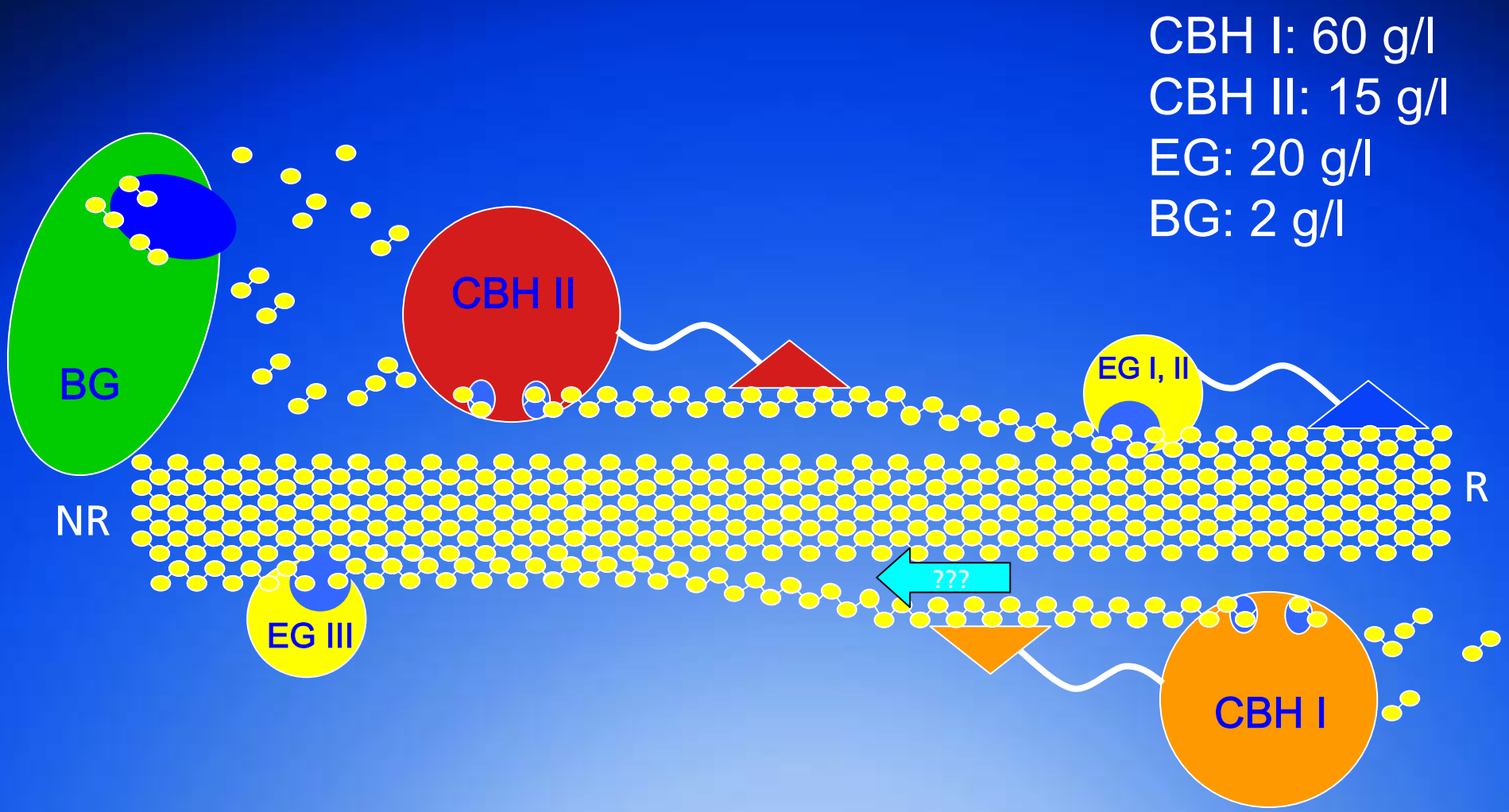
56% Cellulose
5% Hemicellulose
28% Lignin
13% Other



Yield = 72 gallons ethanol/dry ton
= 30 lbs. corn stover/gallon
Enzyme usage ~100 g protein/gallon

novozymes

Fungal Cellulase: a complex, interacting mix



How can Novozymes make enzymes less expensive?

Reduce enzyme production costs by:

- Reduced cost feedstocks
- Reduced enzyme recovery
- On-site production
- Increased fermentation yield

Increase enzyme activity on a per gram basis by:

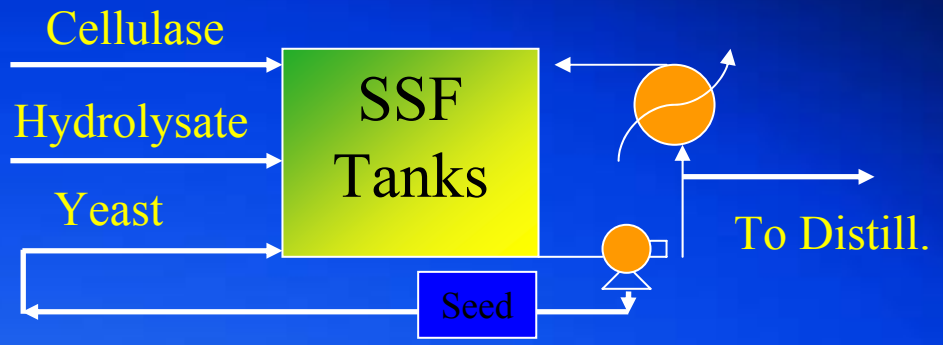
- More thermostable enzymes
- Higher specific activity
- Optimization of cellulase enzyme mix

novozymes

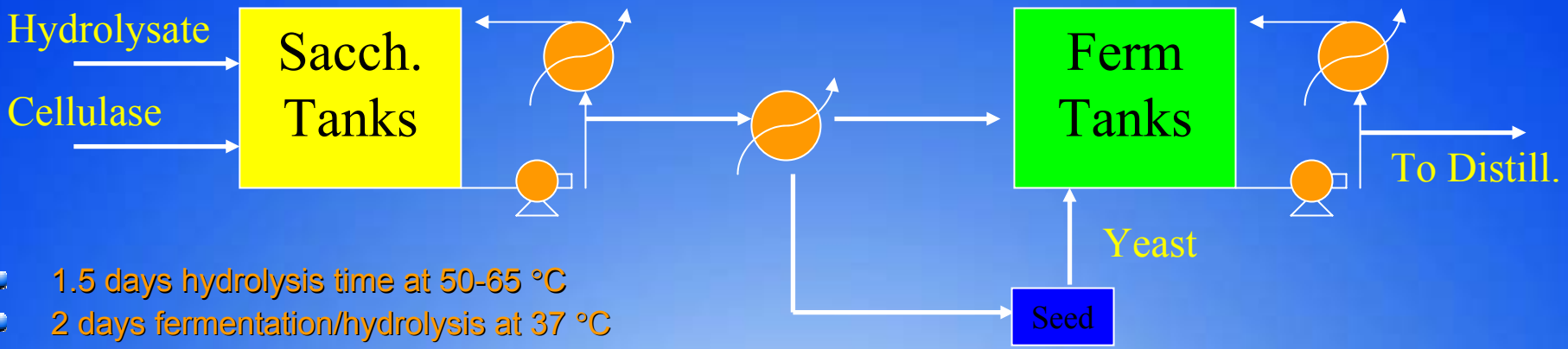
Biorefining Process Scenarios

Simultaneous Saccharification & (Co-)Fermentation (SSF):

- 7 days hydrolysis/fermentation time at 30°C
- 15 FPU/g cellulose loading



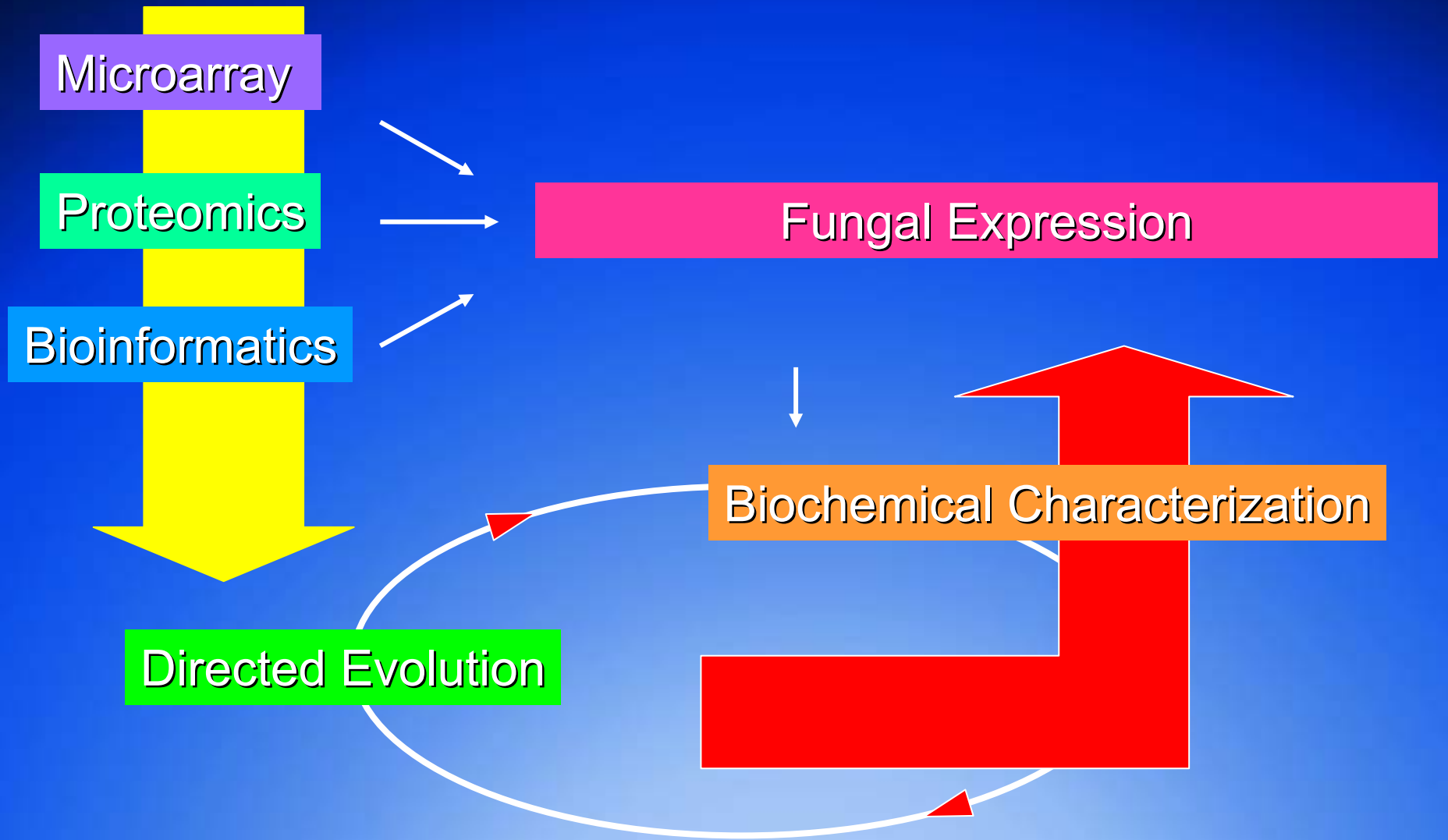
Hybrid Hydrolysis & (Co-)Fermentation (HHF):



- 1.5 days hydrolysis time at 50-65 °C
- 2 days fermentation/hydrolysis at 37 °C
- 12 FPU/g cellulose loading
- Some hydrolysis occurs during fermentation

novozymes

How the BioEnergy Project is organized:

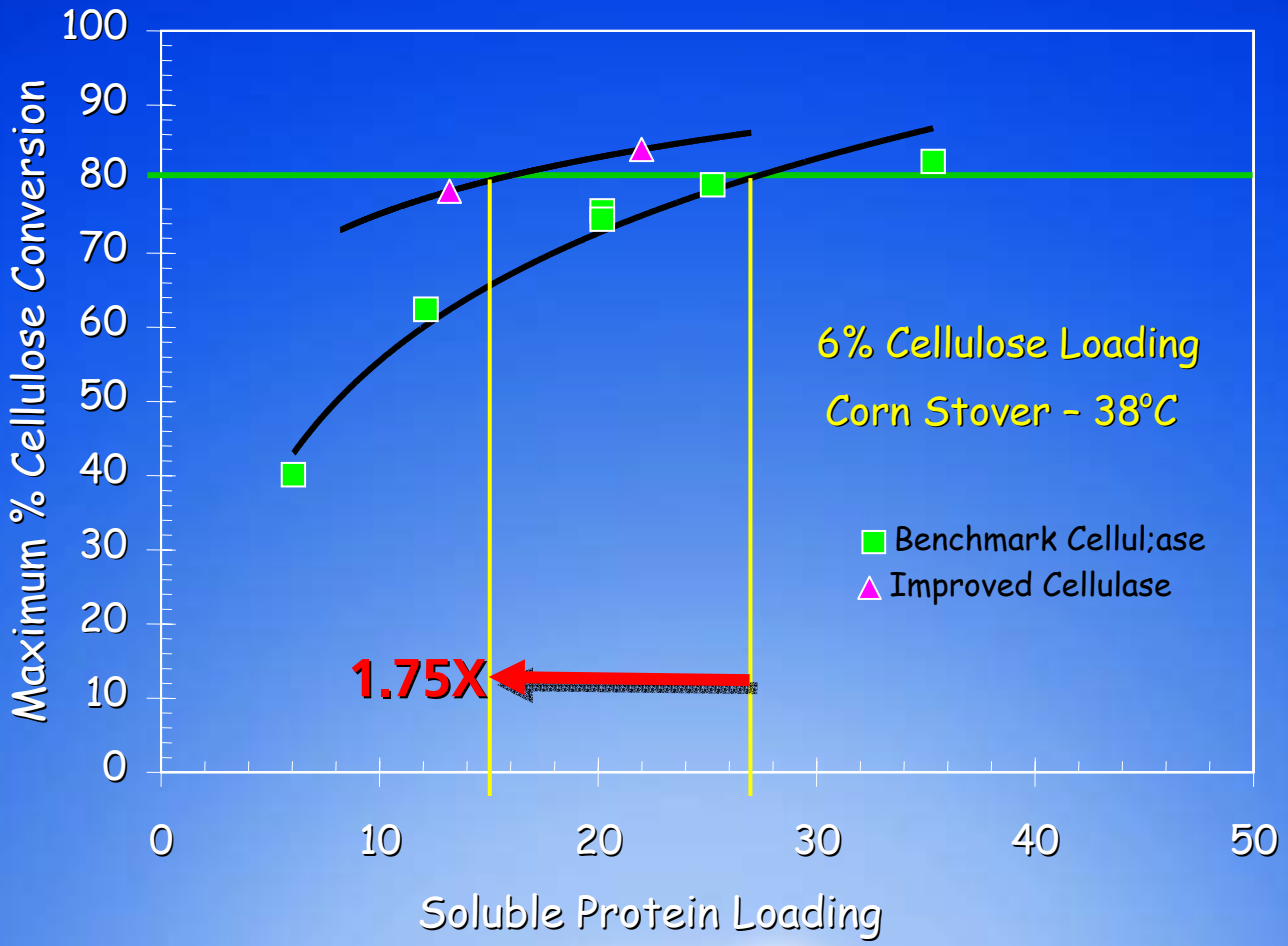


novozymes

NREL Data: Celluclast vs. Celluclast Plus

A 2.3-fold cost reduction as of January 2002

Greater than 5-fold as of January 2003



novozymes

But economics still look challenging…

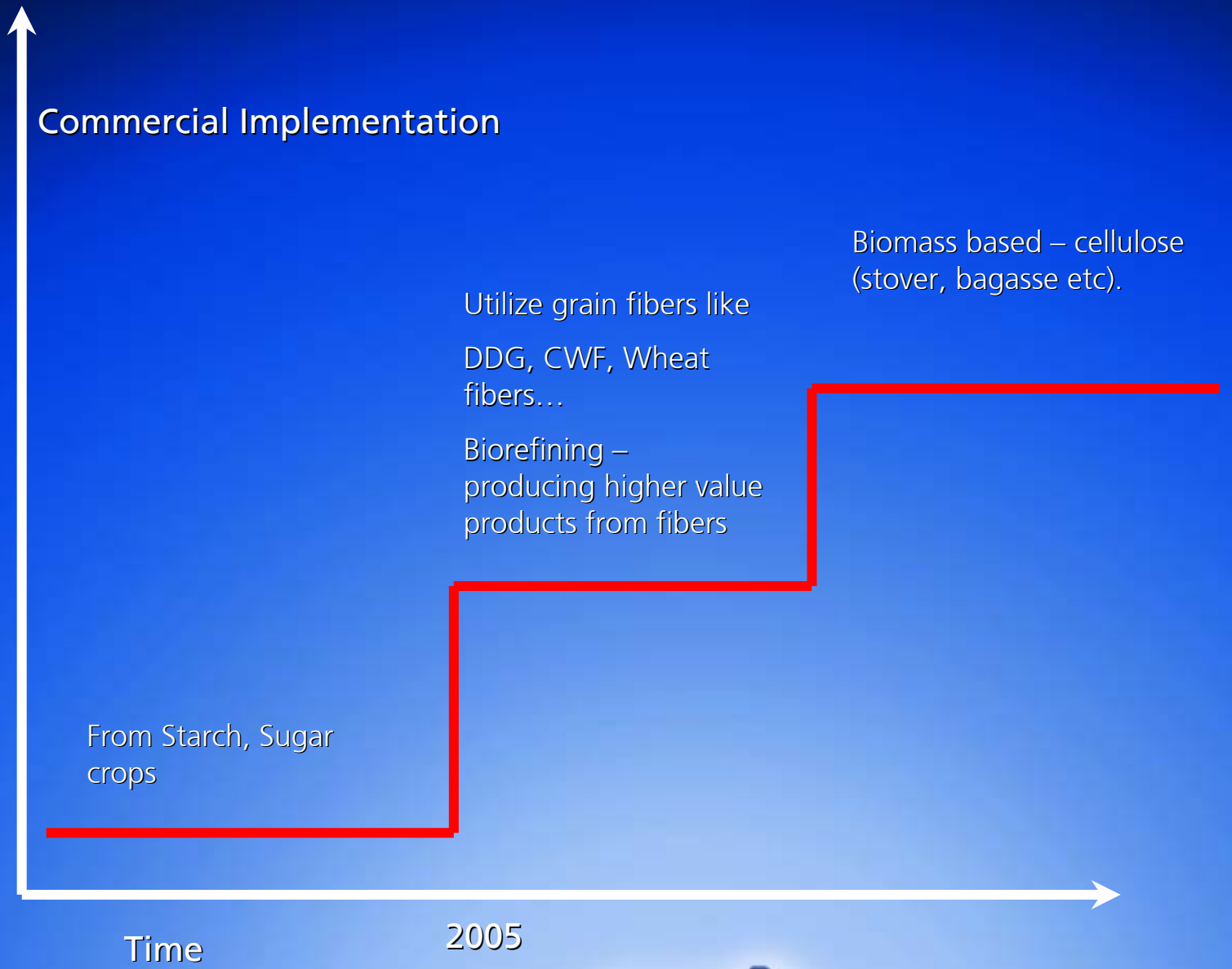
Type of liquid fuel	Production costs – total net costs	Enzyme costs (included in total net costs)*	Market ethanol price
Bioethanol dry milling corn	$1.00-1.20 /gal	~ $0.05 /gal	~ $1.00 /gal
Bioethanol from stover *	~ $6.00-1.80 /gal	$5.30-0.25 /gal	~ $1.00 /gal

*High estimate is at enzyme economy prior to Bioenergy (NREL) project; low at 10X improved and optimistic estimate of new production scenario.

Note: U.S. tax subsidies to the petroleum industry have been estimated to be *at least* $4.00/gallon of gasoline (International Center for Technology Assessment, Report #3, A. Kimbrell)- takes into account defense expenses to retain access to petroleum supplies

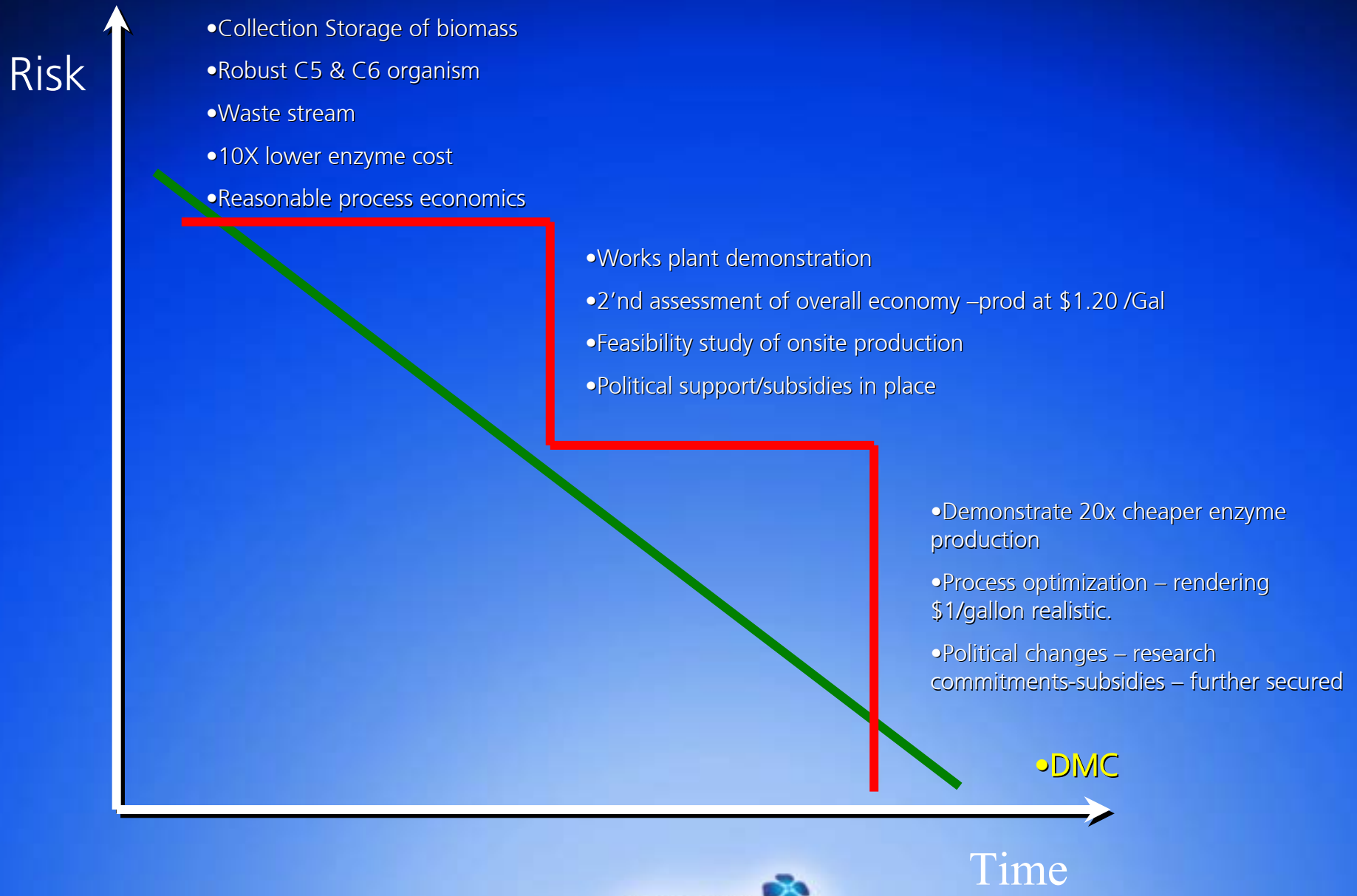
novozymes

Cellulose utilization: A stepwise feasibility/development



novozymes

Ethanol from cellulose requires progress on multiple fronts…



novozymes

NZ's Role in Enzymes for biomass

- As the world's leading enzyme player, Novozymes contributes to making fiber/biomass-based processes technically and economically feasible. The cost effectiveness of the enzyme(s) is the single most important factor for improved feasibility
- As to *on-site production of enzymes*, Novozymes is of the opinion that this is a secondary factor contributing to the overall economic feasibility.
- The solution of other issues – such as enzyme efficiency per gram protein, collection logistics, pre-treatment technology , C5 fermentation – must be further progressed to make on-site enzyme production the 'decisive factor enabling feasibility'

novozymes